ICOLSE 2024

CAMPINAS BRAZIL

9-12 SEPTEMBER 2024

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EMBRAER

LIGHTNING DIVERSION SYSTEMS

80 DG 1943-2023 EXCELLENCE IN AEROSPACE

EMA

航太 Hefei Hangtai Electrophysics Co., Ltd.

September 9		
08:30 – 12:00	**Registration**	
09:00 – 09:20	**Open Ceremony - Dean of Unicamp** Prof. Antonio José Almeida Meirelles	
09:20 – 09:50	**Room 3** **Invited Speaker** - Marcos Vinicius Campos "EMBRAER - C-390 Millenium Development"	
09:50 – 10:20	**Coffee Break & Exhibition**	
10:20 – 10:50	**Room 3** **Presentation by Dayton Granger**	
10:50 – 11:20	**Room 3** **Presentation by LDS - Lightning Diversion Systems**	
11:20 – 11:50	**Room 3** **Keynote Speaker**: Prof. Fernando Galembeck "Electricity and Hydrogen Production at water-air and other aqueous interface"	
12:00 – 01:40 PM	**Lunch**	
	Room 1 **Lightning and Atmospheric Phenomenology**	**Room 3** **Lightning Direct Effects-Composites**
01:40 PM	**A Summary Evaluation of Thermoplastic Composites When Subjected to Direct Effects of Lightning** Rebeka Khajehpour and Alyssa Gonzalez	**Multi-Physics Simulations of Direct Lightning Damage to Elastoplastic Substrates** Jakob J. Schoser, Stephen Millmore, Nikolaos Nikiforakis
02:00 PM	**Investigating strategies for categorizing electric field pulses associated with return strokes and other lightning-related processes** Gustavo Barbosa, Lucas Viegas, Karine Teixeira, Matheus Vianna, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Listz Simões, Miguel Guimarães, Marcelo Arcanjo, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi	**Comparison Between DC and CD current Waveform on Aluminum Panels** Clement Zaepffel, Rafael Sousa Martins, Amelie J and Philippe Lalande

02:20 PM	**Assessing the scalar potential distribution produced by a floating leader using the Finite Element Method** Tiago Luiz Pinto, João Pedro Corrêa, Raphael Floresta Magalhães, Listz Simões, Miguel Guimarães, Kamila Cristina Costa, Marco Aurélio de Oliveira Schroeder, Istvan Kereszy	**Study of an Atypical In-service Lightning Strike on a Commercial Jetliner** Aurélie Bouchard, Christelle Kutyla, Philippe Lalande, Franck Flourens
02:40 PM	**Upward Connecting Leader Initiation in Large-Area** Gilberto Teodósio, Lucas Guimarães, Gustavo Alves, Lucas Silva, Matheus Martins, Deilton Gonçalves, Tulio Carvalho, Miguel Guimarães e Listz Simões	**Study on lightning protection overlaps on composite parts including surfacing film** Alban Douyère-Dumesnil
03:00 – 03:40 PM	**Coffee Break & Exhibition**	
03:40 PM		**Presentation by EMA** - Electro Magnetic Applications
04:00 PM	**New Findings about Atmospheric Electricity Build-up and Dissipation** Fernando Galembeck, Leandra P. Santos, Thiago A. L. Burgo, Andre Galembeck	**Experimental Study of Aeronautical Fasteners Subjected to Lightning Currents** Rafael Sousa Martins,1, Amélie Jarnac, Clément Zaepffel and Philippe Lalande
04:20 PM	**Climate changes and its impacts on lightning phenomenon** Michael TROUBAT	**Benefits of Grating-based X-ray Phase Contrast Imaging to Characterise Lightning-Damaged CFRP** Amélie Jarnac, Laureen Guitard, Adrien Stolidi, Rafael Sousa Martins, Jérôme Primot and Philippe Lalande
04:40 PM	**Wind Tunnel Experiments of Long Arcs in Crossflow** Carmen Guerra-Garcia, Fayleon Lin, Nicolas Gomez-Vega, Sankarsh Rao, Rafael Sousa Martins	**Lightweight Lightning Strike Protection of Aircraft using Coated Expanded Aluminum Foil** Shane Peng, Shawn Duffy, Yong Yeong, Kenneth Burtt, Krishnan Chari
05:30 – 09:00 PM	**Welcome Coquetel** HOTEL CPV - UNICAMP Address	

September 10		
	Room 1 **Lightning Direct Effects-Composites**	**Room 3** **Lightning Zoning**
09:00	**Creeping Leader Surface Spark Discharge on Low-Conductive Natural and Artificial Objects** Stefan Jugelt, Christian Drebenstedt, Michael Rock	**Physics-based zoning of unconventional aircraft: The swept stroke phase** Nathanael A. Jenkins, Carmen Guerra-Garcia
09:20	**Analysis of Laser Parameters for Efficient Quantum Ionization in Air for HV Circuit Triggering** Michal Sakala,Jan Mike˘s, Ondrej Hanus, Marcela Efmertova, Martin Mydlar	**Mix & Match - Introducing a Simplified Methodology for Lightning Zoning of VTOL Aircraft** Marina Sousa, Philippe Lalande, Johan Meuzelaar, Sonia Zehar, Marc Meyer, Matteo Tiana, Murray Marple
09:40	**Modelling of Lightning First Short Stroke Current Waveform by Stepped or Nonlinear Capacitance Discharges** Michael Rock, Stefan Jugelt, Kamila Costa, Christian Drebenstedt	**Zoning from physical models** Philippe Lalande, François Pechereau
10:00 – 10:45	**Coffee Break & Exhibition**	
10:45 – 12:00	**Room 3** **ROUND TABLE "Roundtable on Simulation for Development and Certification"** Franck Flourens	
12:00 – 01:40 PM	**Lunch**	
	Room 1 **Lightning Direct Effects-Composites**	**Room 3** **Lightning and Atmospheric Phenomenology and Detection**
01:40 PM	**Optimization Approach for Earth-Termination System for Large-Scale Solar Power Plant with Pre-Determined Air-Termination System** Eduard Shulzhenko, Kamila Costa, Michael Rock	**Practical Electric Field Modeling Approach to Evaluate Aircraft Initial Attachment Locations for Lightning Zoning** JT Millar, Megan Maguire, Cody Weber, Brock Milford

02:00 PM	**Development of a Grounding System Circuit Model for Transient Analysis Based on Frequency Spectrum of Lightning Current** Jose Luciano Aslan D'Annibale, Walter L. Manzi de Azevedo, Anderson R. Justo de Araujo, Jose Pissolato Filho	**Lightning Nowcast on Airports in the Amazon Region Using Machine Learning** Gabriel A. V. S. Ferreira, Adonis F. R. Leal, Marcio N. G. Lopes, Leonardo C. da Rocha
02:20 PM	**Lightning Incidents At Brest Airport: Consequences, Causes And Solutions** - Sylvain Fauveaux	**A Lightning Simulation Review by Means of Antenna Theory** Rodrigo Rodrigues de Assis
02:40 PM	**Copper Based Lightning Protection: Sustainability Problems And Proposed Solutions** Sylvain Fauveaux, Amaury Lefort	**Review of an Airborne Lightning Detection System and Atmospheric Conditions During Flights in Coastal Thunderstorm Conditions** Zachary Milani, Leonid Nichman, Edgar Matida, Mathieu Lachapelle, Cuong Nguyen, Eric Bruning, Mengistu Wolde, Greg M. McFarquhar, Pavlos Kollias, R. Timothy Patterson
03:00 PM	**Impact of Grounding System Modeling on Overvoltage Waveforms for Direct Lightning Strikes** Wagner Costa da Silva, Walter Luiz Manzi de Azevedo, Anderson Ricardo Justo de Araujo, Jose Pissolato Filho	**Urban Air Mobility Operations: Evaluating Exposure to Lightning Strikes** Evandro F. Ledema, Kleber P. Naccarato, Marina G. Sousa
03:20 – 03:45 PM	**Coffee Break & Exhibition**	
03:45 PM		**Hefei Hangtai Electrophysics Co., Ltd.**
04:00 PM	**Research on Lightning Electric and Magnetic Field Effect Test.** Xiu XIONG, Xiaoyu FAN, Shaohua LI, Kai LIU	**Analysis of the Ebro Lightning Mapping Array detections of aircraft in flight producing electrical discharges** Eduard Martin, Joan Montanyà, Jesús A. López, Oscar van der Velde, Nicolau Pineda, D. Romero, Carlos A. Morales
04:20 PM	**Material characterization for propagating brush discharge threat analysis** Crislane Silva, Eduardo Ferreira, Julio Santos and Janaina Nicolo	**Updated Version Of A Low-Cost Remote Device For Measuring Lightning Currents** Gilberto Teodosio, Lucas Guimaraes, Gustavo Alves, Lucas Silva, Matheus Martins, Deilton Gonçalves, Tulio Carvalho, Miguel Guimar.es e Listz Simões

04:40 PM	**Multi-Chamber Arrester with Impulse Arc Quenching for Protection 13.8 kV Overhead Lines** Georgy Podporkin, Urij Kretov, Alexander Sotnikov, Sergey Rumyantsev	**Evaluating Strategies for Automatically Detecting the Long Continuing Current Signatures on Electric Field Waveforms of Lightning Events Occurring in the Metropolitan Area of Belo Horizonte** Lucas Viegas, Gustavo Barbosa, Karine Teixeira, Matheus Vianna, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Listz
07:00 – 11:00 PM	**Gala Dinner** - Espaço Barão Address	

September 11		
09:00 – 10:00	**Room 3** **Course - MASSOUD - Staff Scientist Lightning Gulfstrem Aerospace "Aircraft Fuel Tank / Systems Design, Certification and Process for Ignition Prevention"**	
10:00 – 10:40	**Coffee Break & Exhibition**	
	Room 1 **Electrostatics**	**Room 3** **Fuel Tank and Fuel Systems**
10:40	**Study on electrostatic characteristics of valve head materials in aircraft oxygen System** Zemin Duna, Wei Yan, Xiaoliang Si , Zhibao Li	**Flammable Gas Mixture Test Fixture Standardizations** Sofia Graham, Derek Tuck, Brian Egenriether, Philipp Boettcher
11:00	**Radiation Hazard of Ball Lightning** Mikhail L. Shmatov	**Benefits of Computational Electromagnetic Analysis in Aircraft Fuel System Lightning Certification** Massoud Sadeghi, William Coleman
11:20	**An End-to-End Physics-Based Modeling Approach to Precipitation Static** Derek Tuck, Brian Egenriether, Nitish Chandra, Kyu-Pyung Hwang	**Simulation of Continuous Arc with Semi-implicit Scheme and Mesh Adaptation** Gabriel Barreau, François Pechereau, Benjamin Khiar, Julien Vanharen, Philippe Lalande, Fabien Tholin, Guillaume Puigt, Frédéric Alauzet

11:40	**The numerical simulation method of charging current in electrostatic deposition environment of aircraft** Duan Zemin, Xiaoliang Si,Tong Chen, Shanliang Qiu, Zhang Song, Zhibao Li, Gong Hanlin, Huang Yeyuan	**From kerosene to hydrogen aircraft: The new lightning protection challenges** Bigand Audrey, Revel Ivan, Emma Roubaud, Flourens Franck
12:00 – 01:40 PM	**Lunch**	
	Room 1 **Lightning and Atmospheric Phenomenology**	**Room 3** **Lightning indirect effects and modelling**
01:40 PM	**Analysis of Electrical Bonding Array Effects on the Protection of Electro-Electronic System Externally Installed on Small Composite Airframe** Diego Faria Amaral, José Antônio de Souza Mariano, Lollan Naru Nonaka Rodrigo Cabaleiro Cortizo Freire, Sidney Osses Nunes	**Numerical Modeling of Induced Transients on A/C Wiring: Use of FDTD Simulations for Falcon 6X Certification** F. Terrade, F. Tristant
02:00 PM	**Lightning Current Tests of Segmented Diverter Strips with Component** Felicitas Modlinger, Christian Karch, Fridolin Heidler	**Numerical Modeling of Induced Transients on Aircraft Wiring with a Hybrid FDTD/MTLN Approach** T. Strub, N. Muot, C. Girard, F. Terrade, F. Tristant, N. Bui, C. Guiffaut, A. Reineix
02:20 PM	**Design of a Small Field Mill Network for Cloud Modelling** Valter Garcia, Miguel Guimarães, Listz Araújo, Tulio Carvalho Lucas Viegas, Deilton Gomes, Marcelo Saba, Moacir Lacerda	**Modelling Lightning Indirect Effect on Aeronautic Systems: Validation from Improved Analytical Formalism and Numerical Simulations** S. Lalléchère, D. Cvetkovic, L. Pniak, Y. Corredores, V. Melchor, A. Piat, F. De Daran, P-E. Lévy, L. Pichon
02:40 PM	**Analysis of Lightning-Induced Effects on Small Electric Aircraft** Renan H. M. Callegari, José Antônio S. Mariano, Rodrigo Cabaleiro C. Freire, Ricardo A. de Araujo, José Pissolato Filho, Gabriel T. C. Francisco	**The Evolution of Indirect Effects Lightning Qualification Test Standards for Airborne Products: An Overview of EUROCAE ED 14 / RTCA DO-160 Section 22, Revision G to H** Vincent Melchor, Bertrand Chatain

03:00 – 03:30 PM	**Coffee Break & Exhibition**	
		Room 3 **Lightning and Atmospheric Phenomenology and Detection**
03:30 PM		**Room 3** **Keynote Speaker:** Prof. Anderson Rocha "Harnessing the AI and Convergence Revolution to its fullest potential"
04:00 PM	Simulation Analysis and Experimental Validation of Direct Effect Damage of CFRP Under Continuous Components of Lightning Current Du Mingxin, Zhu Xuemeng, Zhou Jiadong, Xiong Xiu, Fan Xiaoyu	**Wind turbine blades and reducing lightning damage through retrofits** Billy Martin, Aaron Jones, Harian Sharpe
04:20 PM		**Assessing the time difference of arrival and optimization techniques to determine strike location of lightning events occurring in the metropolitan area of Belo Horizonte** Karine Teixeira, Lucas Viegas, Gustavo Barbosa, Matheus Vianna, Matheus Martins, Listz Simões, Miguel Guimarães, Marcelo Arcanjo, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi
04:40 PM		**A novel network for detecting long continuing currents in the metropolitan area of Belo Horizonte** Miguel Guimarães, Listz Simões, Karine Teixeira, Lucas Viegas, Gustavo Barbosa, Matheus Drumond, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Tiago Pinto, Deilton Gomes, Túlio Carvalho, Guilherme Silva, Elias Freitas, Marcelo Arcanjo, Marcelo M. F. Saba, Paola Lauria, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi
05:00 – 05:20 PM	**CLOSING CEREMONY**	

September 12	
07:30 AM – 04:30 PM	❖ **Technical Visit - Embraer (50 places)**
08:30 AM – 04:30 PM	❖ **SINCROTON LABORATORY**

WELCOME

The International Conference on Lightning & Static Electricity (ICOLSE) is a biennial conference focused on lightning phenomenology, the effects of lightning incidence on and protection of aircraft and other air vehicles, and a wide variety of ground-based systems and facilities such as alternative energy (wind, solar) and any other ground structures. The conference also addresses static electricity generation, its effects, and protection for aerospace vehicles and industrial facilities.

For the first time in the history of the conference, ICOLSE will be held in Brazil and South America! Campinas, an important technological and educational center close to the capital of São Paulo state, will be the city hosting the conference in 2024 at the University of Campinas – UNICAMP.

Brazil is known as a country with receptive and kind people, a festive culture, and an amazing natural environment. You are very welcome to our country. If you are from Brazil, you can join UNICAMP/Campinas.

During ICOLSE2024, besides several technical sessions and presentations, you will have the opportunity to taste the best food from the state, feel our climate, and also, as part of the conference, visit Sirius (Brazilian Synchrotron Light Laboratory) and EMBRAER (in the city of São José dos Campos).

We hope to see you in Campinas next 09-12 September 2024. It will be an exciting and enjoyable conference.

The Organization Committee

CONFERENCE
HISTORY

The International Conference on Lightning & Static Electricity is a biennial conference with the aim bringing together experts from all fields on the subject of lightning and static electric. It is concerned with all aspects of lightning interaction with ground, air and sea systems. Papers will be presented that contain original material to promote discussion at all levels and address problems of present and future technologies.

ICOLSE aims to encourage a real understanding of atmospheric electricity environmental hazards. A full programme of papers on topics from phenomenology, through measurement, design, protection, testing and computational modelling will be presented.

Last three ICOLSE editions saw more than 200 attendees in average representing several companies, government agencies, universities and other organizations. The progress made in advancing the disciplines of lightning and static electricity was evident in the technical programs as well as through workshops and special sessions provided.

List of previous conferences:

- Hosted by Madrid (ESP) 2022;
- Hosted by Wichita (USA) 2019;
- Hosted by Nagoya (Japan) 2017;
- Hosted by Toulouse (France) 2015;
- Hosted by Seattle (USA) 2013;
- Hosted by Oxford (UK) 2011;
- Hosted by Pittsfield (USA) 2009;
- Hosted by Paris (France) 2007;
- Hosted by Seattle (USA) 2005;
- Hosted by Blackpool (UK) 2003;
- Hosted by Seattle (USA) 2001;
- Hosted by Toulouse (France) 1999.

CONFERENCE
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Senior EME Engineer - EMBRAER Commercial Aviation

José Antônio Mariano
Lead EME Engineer - EMBRAER Chief Engineering Office

Ana Paula Berres
Lead EME Engineer - EMBRAER Commercial Aviation

KEYNOTE SPEAKERS

Dr. Franck Flourens
AIRBUS

Dr. Fernando Galembeck
UNICAMP

Massoud Sadeghi
Staff Scientist, Lightning Gulfstream Aerospace

Dr. Anderson Rocha
UNICAMP

Marcos Vinicius Campos
EMBRAER

09 Sept

CONFERENCE TECHNICAL SESSIONS *PROGRAM*

September 09

01:40 – 02:00 PM

Room 1

A SUMMARY EVALUATION OF THERMOPLASTIC COMPOSITES WHEN SUBJECTED TO DIRECT EFFECTS OF LIGHTNING

Rebeka Khajehpour and Alyssa Gonzalez

In recent years, the aircraft industry has started using thermoplastic matrix materials in place of the traditionally used thermoset plastics for composite structures. Since data regarding the ability of thermoplastic composite materials to withstand lightning strikes was not publicly available, the National Institute for Aviation Research (NIAR), funded by the Kansas Aviation Research and Technology initiative (KART) performed a series of tests on generic flat panels. The findings were published in the advanced general aviation transport experiments (AGATE) lightning “Aircraft Skin Protection Effectiveness” handbook. This paper considers a subset of the AGATE data from the project phases covering matrix material comparisons, mechanical aging, and spliced lightning strike protection.

01:40 – 02:00 PM

Room 3

MULTI-PHYSICS SIMULATIONS OF DIRECT LIGHTNING DAMAGE TO ELASTOPLASTIC SUBSTRATES

Jakob J. Schoser, Stephen Millmore, Nikolaos Nikiforakis

In this work, we present a new method to holistically simulate the two-way interaction between a lightning arc and a damageable, elastoplastic substrate. This is achieved by solving a unified set of partial differential equations describing the coupled evolution of compressible fluids and solids under the influence of time-varying electromagnetic fields. This mathematical model is solved on a single computational grid using a shock-capturing finite volume method, where each material is modelled using its own, thermodynamically consistent equation of state, plasticity, and damage model. The model naturally captures material separation, which is important for the simulation of delamination and outgassing. To demonstrate the method, simulations of laboratory experiments are shown to capture the dynamics of the lightning plasma as well as thermal stresses and damage in the substrate.

09 Sept

02:00 – 02:20 PM

Room 1

INVESTIGATING STRATEGIES FOR CATEGORIZING ELECTRIC FIELD PULSES ASSOCIATED WITH RETURN STROKES AND OTHER LIGHTNING-RELATED PROCESSES

Gustavo Barbosa, Lucas Viegas, Karine Teixeira, Matheus Vianna, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Listz Simões, Miguel Guimarães, Marcelo Arcanjo, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi

This study aims to present a preliminary analysis of data recorded by a novel lightning detection network installed in the metropolitan region of Belo Horizonte, Brazil, to evaluate the temporal parameters of bipolar intracloud (IC) pulses and preliminary breakdown (PB) pulses, aiming to enable their separation from pulses related to return strokes (RS). From between the two being the front time, which on average is about 70% shorter in ICP. A detailed explanation of these phenomena, followed by statistical analyses, is elaborated to identify parameters that will subsequently feed into an automatic classification algorithm.

02:00 – 02:20 PM

Room 3

COMPARISON BETWEEN DC AND CD CURRENT WAVEFORM ON ALUMINUM PANELS

Clement Zaepffel, Rafael Sousa Martins, Amelie J and Philippe Lalande

ONERA is studying sweeping of aircraft with wind tunnel and rail gun apparatus to simulate a lightning strike in a take off phase. ONERA has generators capable of producing D and C coupled current waveforms. While the DC combination is the standard order, the CD case is needed to study restrike in the case of sweeping. Our proposed study aims firstly to develop a generator capable of delivering a current waveform with a CD sequence, and secondly, to compare the effects of DC and CD sequences when injected onto aluminium panels, taking into account damage observation, high-speed imaging, and schlieren techniques. These results demonstrates differents behaviour between the two configurations, without an external air flow. These results will prepare a study of an electric swept arc by a cross airflow in a wind tunnel submitted to an impulse current.

09 Sept

02:20 – 02:40 PM

Room 1

ASSESSING THE SCALAR POTENTIAL DISTRIBUTION PRODUCED BY A FLOATING LEADER USING THE FINITE ELEMENT METHOD

Tiago Luiz Pinto, João Pedro Corrêa, Raphael Floresta Magalhães, Listz Simões, Miguel Guimarães, Kamila Cristina Costa, Marco Aurélio de Oliveira Schroeder, Istvan Kereszy

This work proposes an implementation of the Kasemir's bidirectional bipolar leader concept using the Finite Element Method (FEM) to study the electric field levels at the tip of grounded structures produced by thunderclouds and lightning leaders. The goal of this implementation is to compare the preliminary results with those obtained applying the Charge Simulation Method (CSM), which presents some modelling limitations that can be critical when it comes to the evaluation of electric field levels at the tip of grounded structures. From the comparison between the obtained results under the use of both methods, the main conclusions are drawn, namely: the FEM can be successfully used with the support of a friendly interface, such as Ansys Maxwell software; the obtained results for the main study case are similar to those corresponding to the CSM implementation; the electric field levels at the surface of charged objects can be evaluated consistently.

02:20 – 02:40 PM

Room 3

STUDY OF AN ATYPICAL IN-SERVICE LIGHTNING STRIKE ON A COMMERCIAL JETLINER

Aurélie Bouchard, Christelle Kutyla, Philippe Lalande, Franck Flourens

In February 2019, an A320 aircraft operating in the mediterranean region experienced a severe lightning-strike event. This severe event resulted in the opening of a few Overhead Stowage Compartments (OHSCs) as well as the breakage of some of their hinges, injury to eardrums of crew members, drop of some Oxygen masks, etc. This exceptional reported event deserved the launch of a detailed study to understand the operating conditions at the time of the event and to take the lessons learnt from such a singular case. Because this can be of interest to the whole aviation community, the ONERA offered to contribute to the analysis and to support Airbus, specifically for the understanding of the atmospheric conditions in relation with the storm dynamic and lightning risk in the area. Measurements from the ground-based Global Lightning Detection Network (GLD360) indicated electrical activity in the area of the event and on the date of the event, including both cloud-to-ground flashes of both polarities, and intra- or inter-cloud pulses. A meteorological analysis was conducted to understand the atmospheric conditions that may have led to the presence of thunderstorms associated with lightning activity in this area on the date in question. This analysis

utilised both satellite observations and outputs from numerical weather prediction models to assess atmospheric instability, as well as the factors that enabled the development of the convection and electrical activity. Moreover, attention was focused on how the presence of the jet stream (area of strong zonal winds) over Italy on this date impacted the development of the thunderstorm. The likely cause of the damage to the OHSCs is mechanical and air-pressure shockwaves caused by the lightning strike. The damage found on the fuselage at the lightning impact point coupled with the injuries to the crew due to the lightning detonation corroborate the hypothesis of a high-intensity lightning flash, essentially composed of single and severe strike with almost no continuous component. Furthermore, the impact point was found in an area identified as a swept stroke zone without any evidence of dwell attachment points ahead, and was not associated with protrusions, structural tips or any feature reinforcing local E-fields prone to developing streamering. This suggests the scenario of an intercepted lightning strike at the stage of the return stroke, which is less common than triggered lightning. In addition, the data recorded by the ground lightning surveillance network indicate that the flash was positive with a specific 200kA-class strike identified in the area. Whilst only about 10% of in-flight lightning flashes are positive with a higher probability of a severe strike intensity, the very high count of cumulated Flight Hours of Airbus aircraft makes such events likely to be observed at the level of the fleet. This unconventional event also raises questions about the overall certification process. The event was severe and potentially going beyond standard lightning criteria and the zoning didn't identify a severe impact at the location it was observed. However, it demonstrates as well that the overall process is robust, thanks to the Lightning Hazard Analysis aimed at identifying and accounting for the most severe scenarios, and for inherent uncertainties in the phenomenology. Finally, we would like to advise the overall aviation community to systematically report, analyse and publish unconventional cases as it can be weak signals of a potential evolution of the overall level of exposure of a civil aviation fleet.

02:40 – 03:00 PM

Room 1

UPWARD CONNECTING LEADER INITIATION IN LARGE-AREA PHOTOVOLTAIC PLANTS FOR NEGATIVE LIGHTNING

Kamila Costa, Sven Wolfram, Michael Rock, Armando Heilmann, Tiago Pinto, Miguel Guimaraes

This study investigate the conditions for the initiation of lightning upward connecting leaders (UCL) in large-area photovoltaic (PV) plants to enable the assessment of the most likely strike points on the PV array. The methodology, based on the Charge Simulation Method (CSM), is implemented in MATLAB, considering in-depth studies on lightning physics to describe the mechanism of the lightning strike with the necessary assumptions to simplify while maintaining a physically

consistent model. The evaluation of possible UCL inception in the PV array is conducted by analyzing the electric field in the vicinity of the PV panels, a necessary condition for the formation of streamer corona discharges at the edges of the PV panels. To compare with a situation prior the erection of the PV plant, the analysis is also performed to the flat ground. In order to validate the results obtained with the implementation of the CSM, simulations based on the Finite Element Method (FEM) are performed to evaluate the electric field levels in the vicinity of the conductors, overcoming some limitations of the CSM due to the effect of proximity. With the support of the software Ansys Maxwell as a user-friendly interface for the FEM approach, the electric field at the leader tip and on the PV array structure is evaluated more consistently and the results are similar to those obtained by applying the CSM. In summary, this evaluation provides insights for studies on safeguarding large-area PV systems against lightning strikes, thereby advancing external lightning protection strategies in renewable energy infrastructure.

02:40 – 03:00 PM

Room 3

STUDY ON LIGHTNING PROTECTION OVERLAPS ON COMPOSITE PARTS INCLUDING SURFACING FILM

Alban Douyère-Dumesnil

The aim of the current study is to highlight the phenomenon of cosmetic defect at overlap level by reproducing it in a laboratory and to propose improved solutions to reduce the cases of cosmetic defects in service. Different types of overlaps are investigated on different protection solutions, like Expanded Copper Foil (ECF) and Perforated Copper Foil (PCF). High-speed cameras as well as thermal cameras are used to visualize the heating phenomenon during the current flow in these areas.

This paper will present the result analysis of this experimental characterization and will review all the generated defects. A discussion over the different protection strategies is made to isolate the best solution.

04:00 – 04:20 PM

Room 1

NEW FINDINGS ABOUT ATMOSPHERIC ELECTRICITY BUILD-UP AND DISSIPATION

Fernando Galembeck, Leandra P. Santos, Thiago A. L. Burgo, Andre Galembeck

Water plays a major role in generating atmospheric electricity, which, in many cases, can be understood by considering the role of water in matter electrification. A new picture of electrostatic phenomena emerged during the past twenty years, following the discovery of charge mosaics in insulators and the atmospheric water vapor's ability to exchange charge with solids and liquids. Related findings are the unique position of water in the triboelectric series and charge separation during phase

transitions of water. These and other intriguing effects are now explained by water ion partition at interfaces. The new picture of matter electrification includes the Maxwell-Wagner-Sillars effect on interfacial electrification and the various processes that manifest this effect. Still, the discovery of chemical reactions in the electrified interfaces of insulators revealed a connection between chemical and electrostatic phenomena that creates new perspectives for radical change in energy and chemical production. Moreover, this new knowledge contributes plausible explanations for hitherto challenging atmospheric electrical phenomena, including a mechanism for high voltage production in clouds.

04:00 – 04:20 PM

Room 3

EXPERIMENTAL STUDY OF AERONAUTICAL FASTENERS SUBJECTED TO LIGHTNING CURRENTS

Rafael Sousa Martins,1, Amélie Jarnac, Clément Zaepffel and Philippe Lalande

This study characterizes the relationship between dissipated electrical energy and pressure buildup in fastener cavities during lightning current waveforms. It involves experimental evaluations of titanium fasteners installed in aluminum and Carbon Fiber Reinforced Polymer (CFRP) samples. Various configurations are tested under pulsed current waveforms derived from D-component of aerospace recommendation documents, featuring peak levels from 1 to 10 kA. The samples are designed with simplified geometry to control the electric current in the instrumented fasteners. Differential voltage probes allow to estimate the electrical energy, while a piezoelectric sensor measures pressure rise. A parametric study observes the influence of current peak, clearance fit level, sample material, and fastener coating. The results highlight the significance of these parameters, particularly the effect of coating on maximum overpressure inside the fastener cavity.

04:20 – 04:40 PM

Room 1

CLIMATE CHANGES AND ITS IMPACTS ON LIGHTNING PHENOMENON AN ECO-RESPONSIBLE

Michael Troubat

This paper proposes an analysis of the climate change since the last decade and what would be the impact on storm and lightning on Earth. This document is a compilation of various studies done and aims at giving an objective analysis of the modification of lightning events.

This climate change must force us to think differently the lightning protection and how and where installing protection. Moreover due to rarefaction of raw materials, we must look at solution less resource consuming.

09 Sept

04:20 – 04:40 PM

Room 3

BENEFITS OF GRATING-BASED X-RAY PHASE CONTRAST IMAGING TO CHARACTERISE LIGHTNING-DAMAGED CFRP

Amélie Jarnac, Laureen Guitard, Adrien Stolidi, Rafael Sousa Martins, Jérôme Primot and Philippe Lalande

In this work, we develop X-ray Phase Contrast Imaging to provide a robust and quantified characterisation of the density change due to lightning damage in a CFRP. We exploit the fact that the phase shift is proportional to the density of the material. To measure the phase shift, we shape the X-ray intensity in a 2D reference checkerboard pattern that is deformed by the damaged CFRP and reveals the phase gradients in multiple directions (0°, 45°, 90°, -45°). The use of a checkerboard also allows to track measurement errors and therefore the confidence we can have in the different imaged areas. After this validation, the phase is retrieved and quantified using a standard material (PMMA). From there, we can compare the density of the lightning-damaged CFRP with the density of a non-damage CFRP.

04:40 – 05:00 PM

Room 1

WIND TUNNEL EXPERIMENTS OF LONG ARCS IN CROSSFLOW

Carmen Guerra-Garcia, Fayleon Lin, Nicolas Gomez-Vega, Sankarsh Rao, Rafael Sousa Martins

Lightning attachment to aircraft follows a series of distinct phases occurring at disparate timescales. Whereas the stages of leader inception and initial attachment are fast compared to the fluid timescales, once the bidirectional discharge is established, the current flow phase can last on the order of a second: including, current pulses of amplitude ~1kA associated with the stepped propagation of the negative leader, a steady current component (of a few hundred A) and a series of intracloud, cloud-to-ground or cloud-to-cloud process pulses (<100kA). During this time, which corresponds to the most damaging phases of the arc, the aircraft can travel several times its length. At the local level, this swept stroke phase involves the complex interaction between a long arc and a fluid boundary layer. Improved understanding of this local problem can lead to revised modelling approaches of the swept stroke phase. In this contribution we perform wind tunnel experiments of a long arc in cross flow and perform synchronized diagnostics of both the fluid dynamics and the arc dynamics, as a first step to tackling the local problem of lightning attachment associated with the swept stroke. Although the swept stroke phase is most closely represented by a moving electrode setup (the arc column is stagnant with respect to the ambient air and the segment attached to the surface experiences the relative velocity), wind tunnel tests can be useful to isolate the effects of different flow fields on the arc dynamics, as the environment can be easily controlled. In this joint effort between the Massachusetts Institute of Technology, the Universitat Politècnica de Catalunya, and ONERA, we have

initiated wind tunnel studies of long arcs, starting from an arc column of length around 20-80cm and currents of ~3A. The experimental setup is equipped to diagnose both the arc properties and the fluid flow. The arc is characterized by its electrical signature (time-resolved current and voltage waveforms) as well as high-speed videography to resolve the elongation of the arc in response to the flow and possible reconnection and reattachment events. The fluid flow field is visualized in 2D using particle image velocimetry (PIV). This setup allows to isolate the influence of the flow dynamics (laminar versus turbulent, separation, etc.) on the arc dynamics.

04:40 – 05:00 PM

Room 3

LIGHTWEIGHT LIGHTNING STRIKE PROTECTION OF AIRCRAFT USING COATED EXPANDED ALUMINUM FOIL

Shane Peng, Shawn Duffy, Yong Yeong, Kenneth Burtt, Krishnan Chari

Expanded metal foils (EMF) are used in composite structures on aircraft to provide lightning strike protection. These are typically either aluminum or copper foil. From a performance aspect, aluminum is a better material because of its higher heat of fusion and vaporization per unit mass compared to copper allowing for a much lower weight material to be utilized. However, aluminum is more prone to galvanic corrosion when in contact with carbon fibers in the composite structure requiring a fiberglass isolation layer between the materials to prevent corrosion. The isolation layer adds extra weight and manufacturing complexity to the composite system. We present a new approach wherein a conformal coating is applied to the aluminum mesh to protect it from galvanic corrosion. The PPG coated aluminum mesh eliminates the need for an isolation layer in the composite layup resulting in significant weight reduction while retaining the benefits of aluminum over copper for lightning strike protection. Eliminating the isolation layer, the weight of the overall aluminum lightning strike system is reduced by up to 73% and up to 48% compared to the current expanded copper system. Our results show that the PPG coated aluminum mesh will maintain lightning strike protection while achieving equivalent galvanic corrosion protection when compared to the combination of uncoated mesh and isolation layer.

10 Sept

September 10

09:00 – 09:20

Room 1

CREEPING LEADER SURFACE SPARK DISCHARGE ON LOW-CONDUCTIVE NATURAL AND ARTIFICIAL OBJECTS

Stefan Jugelt, Christian Drebenstedt, Michael Rock

How can the lightning strike into a dry tree beexplained or is the starting of an upward leader discharge at a towering object of insulating material possible? These electrical discharge processes can be explained by creeping spark and flashover at the air-insulator interface on these objects. For this, a network modelling approach for the creeping discharge is presented and based on the theoretical investigations as well as scaled experiments, it could be shown that a rapidly propagating creeping discharge leads to a flashover of the object made of insulating material in times significantly shorter than a microsecond and subsequently an upward leader can start immediately from its tip.

09:00 – 09:20

Room 3

PHYSICS-BASED ZONING OF UNCONVENTIONAL AIRCRAFT: THE SWEPT STROKE PHASE

Nathanael A. Jenkins, Carmen Guerra-Garcia

Lightning zoning is a critical exercise for the design and certification of the lightning protection measures of aircraft. As the aviation industry powers towards a low-emission future, novel zoning methodologies, compatible with non-standard aircraft configurations, need to be devised. Current practices for evaluating the swept stroke region (zone 2) rely on empirical models, which are trusted for 'tube-and-wing' concepts, but their validity remains unproven for less conventional, next-generation aircraft. Physics-based models, which are increasingly feasible with modern computing capabilities, have the advantage that they are agnostic to the particular aircraft being considered and theoretically do not require prior experience with that vehicle. Therefore, the use of physics-based models for lightning zoning might be the only path to certify aircraft for which no in-service experience is available. They will also align industry standards for zoning with the state-of-the-art in engineering simulations. In this contribution, we present a physics-based model for the swept stroke zone, building on previous work which identified initial attachment points (zone 1). The swept stroke is simulated using an idealized lightning arc, which is linearly advected in a flowfield, and realistic flowfields for 3D aircraft models are obtained using computational fluid dynamics (CFD). The proposed tool uses physical models for reattachment and reconnection of the arc and also tracks the delivery of current to the aircraft surface. Any number of arcs can be simulated in parallel, randomly positioned in the first lightning zone. The distributions of attachment probability

and dwell time across the aircraft surface can be mapped to identify lightning zones 2A (swept stroke) and 2B (swept stroke with long hang-on). This work presents results of the swept stroke model for various aircraft configurations. First, data from the NASA Storm Hazards Program is compared to simulated results on the Convair F-106B to validate the behavior of individual lightning arcs and to understand the effect of simulated flight conditions. The model is found to be most sensitive to aircraft attitude, while altitude does not significantly impact results. The Storm Hazards Program data also validates the model's ability to simulate the distribution of attachment probability over the aircraft surface. Second, a generic commercial aircraft is 'zoned' and compared to published zoning diagrams to validate the output of simulationswith thousands of arcs, focusing on mapping probability and dwell time data into a zoning diagram. Finally, the model is applied to different unconventional aircraft configurations to demonstrate a zoning result which could not have been achieved. This work was partially funded by The Boeing Company. Following the current Aerospace Recommended Practices.

09:20 – 09:40

Room 1

ANALYSIS OF LASER PARAMETERS FOR EFFICIENT QUANTUM IONIZATION IN AIR FOR HV CIRCUIT TRIGGERING

Michal Sakala,Jan Mikeˇs, Ondrej Hanus, Marcela Efmertova, Martin Mydlar

This paper focuses on advanced methods for triggering high-voltage (HV) circuits via quantum ionization. The methods include reducing electrode spacing, pressure reduction, and active ionization using a laser beam. The main objective of this paper is to analyze and optimize laser parameters for efficient air ionization, which is crucial for the reliable and accurate triggering of HV circuits. Laser triggering offers the advantage of minimal interference with the triggering circuits and mechanical damage, which is essential for applications requiring precise ionization control. The experimental part involves measuring the laser-induced change in breakdown voltage with variable power settings, beam focus, number of pulses, and wavelength. Results show that optimizing laser parameters is crucial for achieving the desired efficiency and reliability of the triggering process. This work provides important insights for further research and practical industry and scientific research applications.

09:20 – 09:40

Room 3

MIX & MATCH - INTRODUCING A SIMPLIFIED METHODOLOGY FOR LIGHTNING ZONING OF VTOL AIRCRAFT

Marina Sousa, Philippe Lalande, Johan Meuzelaar, Sonia Zehar, Marc Meyer, Matteo Tiana, Murray Marple

The variety of VTOL aircraft developed today feature properties unlike any other 'common' existing aircraft: first of all their unconventional shape, but also their unique

operational usage and their fully electric and distributed propulsion. Moreover, their novelty implies that no in-service data exists yet. For VTOL types foreseen to have all-weather capability, protection against the direct and indirect effects of lightning strike needs to be designed and certified. Because of their unique features and the lack of operational experience, the derivation of a specific lightning zoning for VTOL's poses quite a challenge. To find a solution to this issue, a specific task group (SG-9) of EUROCAE working group WG-112 on VTOL has developed a simplified geometrical methodology for determination of VTOL zoning, based on the existing principles of ED-91A [1]. It is therefore not a new methodology by itself, but more an adaptation of a well-known procedure with more analysis steps and attention for VTOL specifics. Equivalent threat levels as currently defined in ED-84A [2] for conventional fixed and rotary wing aircraft will be assumed. The methodology introduced is called 'Mix & Match' and it is considered to be a reasonable worst-case approach leading to a conservative zoning. The fundamentals of the proposed approach are to make use of partial similarity to conventional fixed and rotary wing aircraft: for the different flight phases (hover, transition and cruise: all having specific speed, altitude, propulsion lay-out parameters) of the VTOL, the most applicable existing zoning of ED-91A is adapted for the considered VTOL. The final zoning is the most severe overlap of the analyzed individual flight phase zonings. This paper aims to lay out the principles of the proposed lightning zoning methodology. Moreover, it will explain some of the assumptions made, limitations, alternatives and considerations for VTOL lightning zoning.

09:40 – 10:00

Room 1

MODELLING OF LIGHTNING FIRST SHORT STROKE CURRENT WAVEFORM BY STEPPED OR NONLINEAR CAPACITANCE DISCHARGES

Michael Rock, Stefan Jugelt, Kamila Costa, Christian Drebenstedt

Due to the varying nature of lightning events, the wave shapes of the same type of lightning currents differ significantly. Typical descriptions of the wave shape in form of (multi) exponential approximations are aimed to provide handy equations to describe the energy turn over within the discharge channel. However, for considerations where the leader growth phase is of particular interest, these approximations may oversimplify the physical nature of the stepped downward and upward leader growth and its associated pre-discharge current. Further on, they assume an impressed discharge current instead of a cloud charge, which may not be appropriate for some cases. So, with the help of capacitive-resistive equivalent circuit diagrams, in which capacitances are switched or steadily increased, the temporal change of the electric field during the development of lightning leaders is simulated. Both discontinuous pre-growth in jerk steps or

continuous steady pre-growth of leaders are considered here. As a result, the front part of lightning first short stroke impulse currents can be calculated in more detail either analytically or numerically.

09:40 – 10:00

Room 3

ZONING FROM PHYSICAL MODELS

Philippe Lalande, François Pechereau

Zoning is usually performed for conventional airplanes and helicopters, by a similarity approach described by the ED-91A/ARP-5414B [1] . For new concepts with non-conventional external shape, such as VTOL, there is no in-service experience from which derived a similarity approach. Numerical models can be used to overpass this issue if they are based on the physics of the lightning strike and not empirical laws that need in-service data to be tuned. ONERA has been developing for many years physical methods to build a zoning. This method considers the fundamental processes occurring during a lightning strike to aircraft. The attachment process is computed from the aircraft geometry and the atmospheric electric field direction leading to the lightning inception. The results of this computation give the initial points on the fuselage where a lightning can develop and their probability of inception as a function of the skin geometry and the field direction. These inputs are used in a swept model to compute, for each attachment point, the lightning arc root displacement due to the aircraft motion, the airflow and the lightning channel geometry. From this method, a database including the attachment points and the sweeping points is performed. From this database, a probabilistic zoning can be done by using an experimental database giving the statistical time of arrival of the stroke number k and by assuming a probability distribution of the direction of the atmospheric electric field. The purpose of the paper is to present the model built by ONERA. In a second part, the ONERA model is applied to conventional and non-conventional aircraft and the results are discussed.

01:40 – 02:00 PM

Room 1

OPTIMIZATION APPROACH FOR EARTH-TERMINATION SYSTEM FOR LARGE-SCALE SOLAR POWER PLANT WITH PRE-DETERMINED AIR-TERMINATION SYSTEM

Eduard Shulzhenko, Kamila Costa, Michael Rock

This paper presents a new approach for optimizing the external lightning protection system (LPS) for large-scale solar power plants (SPPs). Unlike traditional methods, which treat the design of the air-termination system (ATS) and the earth-termination system (ETS) independently, this approach considers both systems together. Integrating both systems provides greater flexibility, enabling the construction of a more efficient LPS, conserving materials, reducing transient ground potential rise

(GPR), and ensuring personal safety. Additionally, this approach addresses current challenges by preventing direct lightning strikes to SPP components (such as PV panels), avoiding shadowing, and not interfering with cleaning robots.

The introduced approach proposes that the design process begins with the ATS. In this way, the ATS establishes fixed injection points for the lightning current within the ETS, allowing the ETS to be designed more effectively around these entry points.

It is well known that to control GPR during a lightning discharge, more earth electrodes should be placed within an impulse-effective area, whose size is defined by the frequency and the soil conductivity. The key question that arises is the configuration or system in which these earth electrodes should be arranged within the discharge area around the entry points to account for proximity effects and the effective length at the relatively high frequencies associated with lightning impulse currents.

Firstly, the computational models are implemented in the XGSLab software to find an optimal earthing electrode arrangement for entry points based on electromagnetic field theory, addressing challenges in managing high-frequency and transient behavior during lightning strikes. Secondly, an investigation is conducted using the Dynamic Electro-Geometrical Model (DEGM) to determine the potential locations of the lightning masts within the observed SPP. These strategically placed masts will be located away from the components of the SPP, thereby protecting sensitive panels and power systems from the direct lightning strikes and reducing induced voltages. The masts can be extended when a thunderstorm approaches to avoid shadowing.

Thus, a newly shaped ETS, based on the location of the lightning masts, is further analyzed in terms of earth resistance, personal safety, and material consumption using XGSLab. The primary goal of this initial investigation is to provide an alternative approach for designing LPS for SPP that addresses current challenges.

01:40 – 02:00 PM

Room 3

PRACTICAL ELECTRIC FIELD MODELING APPROACH TO EVALUATE AIRCRAFT INITIAL ATTACHMENT LOCATIONS FOR LIGHTNING ZONING

JT Millar, Megan Maguire, Cody Weber, Brock Milford

This paper demonstrates a practical simulation approach to identify initial attachment locations on aircraft as part of the lightning zoning process. The aircraft model utilized to demonstrate the approach is a simplified F-16 aircraft. A method is proposed to utilize static electric field backgrounds and the associated field enhancement around the aircraft to determine initial attachment locations. The FDTD approach is used to capture three primary coordinate direction orientations of electric field. The electric field enhancement factors are captured at vehicle extremities, and numerous field orientation possibilities are calculated

using linear vector combinations of the three primary field orientations. Once the simulation results are obtained, some discussions are provided as to what constitutes an initial attachment location based on field enhancement levels, and recommendations for finalizing initial attachment zones are made. In addition to the baseline case, sensitivity assessments evaluating different cell sizes and increments of field orientation are performed.

02:00 – 02:20 PM

Room 1

DEVELOPMENT OF A GROUNDING SYSTEM CIRCUIT MODEL FOR TRANSIENT ANALYSIS BASED ON FREQUENCY SPECTRUM OF LIGHTNING CURRENT

Jose Luciano Aslan D'Annibale, Walter L. Manzi de Azevedo, Anderson R. Justo de Araujo, Jose Pissolato Filho

Ground Potential Rise (GPR) generated by lightning strikes can result in hazardous voltages near hit structure. In this context, several models have been developed in the literature to accurately represent the grounding systems of Lightning Protection Systems (LPS), taking into account more realistic soil characteristics. Utilizing an appropriate model that generates approximate results for diverse LPS geometries, a direct time-domain assessment of GPR can provide an efficient and fast estimation. This is particularly valuable in the development of practical resources for LPS projects, encompassing the analysis of physical installation aspects and the evaluation of risks linked to concealed grid ruptures or disconnections, and potential enhancements through alterations in electrode geometries and positioning. The influence of frequency-dependent soil parameters (FDSP) is crucial and cannot be overlooked when attempting to realistically express GPR, especially for higher soil resistivity. This article introduces an method known as the Filtered Frequency Spectrum Method (FFSM) to efficiently evaluate GPR while considering FDSP. The simulations utilize a simplified grounding system circuit model incorporated into ATP-EMTP software. The frequency spectrum of the lightning current is obtained through a Fast Fourier Transform (FFT); the spectrum is then segmented into bands using filters to select a representative frequency where the FDSP are evaluated. For each band, a circuit model is constructed using Transmission Line Modeling. The resulting GPR is calculated as the sum of the filtered results. Results demonstrated that the GPR calculated using the FFSM presents a good agreement compared with those assessed with traditional recursive methods. The performance of the FFSM is better for soils of low and moderate resistivity and does not require the traditional frequency-to-time conversion tools.

10 Sept

02:00 – 02:20 PM

Room 3

LIGHTNING NOWCAST ON AIRPORTS IN THE AMAZON REGION USING MACHINE LEARNING

Gabriel A. V. S. Ferreira, Adonis F. R. Leal, Marcio N. G. Lopes, Leonardo C. da Rocha

Lightning poses a potential threat to aircraft and the aviation industry in general, including airports. The lightning hotspots in the Brazilian Amazon region are located in the same regions as the most important airports. The Amazon region airports are vital for the rapid transport of humanitarian aid, especially to support indigenous territories. In this paper, we choose the Belem International Airport as a target place to predict lightning activity. The innovative approach uses solely grided lightning data as input features for lightning prediction. The approach relies on training a machine learning model (ResNet). Data from 2019 was used for training, and data from 2020 was used for testing, so the overall performance of the predictor is higher than 89%.

02:20 – 02:40 PM

Room 1

LIGHTNING INCIDENTS AT BREST AIRPORT: CONSEQUENCES, CAUSES AND SOLUTIONS

Sylvain Fauveaux

Lightning protection covers a wide spectrum of activities. As a result, the damage and consequences can be just as varied and more or less serious. Apart from damage, an equally important factor is continuity of service. Guaranteeing continuity of service as far as possible undoubtedly represents an additional or more complex challenge than lightning protection, which ensures at first the absence of serious damage.

This paper presents the case of Brest-Bretagne airport in Guipavas, France. Since the airport was expanded in 2007 with a new terminal and control tower, it was directly impacted for the third time in December 2023, resulting in a total of 5 days of complete air traffic stoppage since 2007. Equipment was damaged and destroyed, preventing continuity of service at the airport.

The services provided by the control tower to ensure continuity of service are crucial to the safe and efficient operation of an airport. To carry out its missions, the control tower houses not only personnel, but also sensitive equipment, notably for communicating with pilots, but also with the staff of the attached technical block, and the vehicles on the manoeuvring area.

The Brest-Bretagne tower has several antennae at the top of the lookout which provide all these services, particularly to pilots. All these antennae and other sensors/beacons, positioned at the top of the structure, can therefore be struck by lightning. The lightning current can strike the inside of the structure and the devices to which these antennas are connected. These devices are essential to the airport's

continuity of service, and are sensitive by nature. The electromagnetic radiation from the lightning current circulating in the down conductors can also create induced disturbances in the cables located on the roof. Current standards require or recommend that all entry points for lightning disturbances be treated, and specify procedures to reduce the harmful influence of indirect lightning effects.

The Lightning Protection System (LPS) initially added to the new control tower building in 2007 was not sufficient to provide effective protection against lightning and ensure continuity of service. Recommendations issued by the Direction Générale de l'Aviation Civile (DGAC, French General Directorate of the Civil Aviation) in June 2020 provide a comprehensive set of effective solutions to ensure continuity of service in the event of lightning strikes. This paper presents the various solutions to be applied to the structure and equipment in the tower building.

In the near future, a major trend is taking shape in France (and Europe) towards the automation of many airport control services. These cross-functional, integrated systems will be even more interconnected and interdependent. They will need to be carefully protected against lightning strikes.

02:20 – 02:40 PM

Room 3

A LIGHTNING SIMULATION REVIEW BY MEANS OF ANTENNA THEORY

Rodrigo Rodrigues de Assis

A review of some antenna concepts applied to the event of a lightning flash is presented in this work, in which the lightning path is considered as the antenna radiating element. Simulations using a commercial software tool are performed for some randomly chosen paths and an aeronautical scenario is evaluated by adding an aircraft into the simulation models. Some antenna figures of merit are presented and evaluated.

02:40 – 03:00 PM

Room 1

COPPER BASED LIGHTNING PROTECTION: SUSTAINIBILITY PROBLEMS AND PROPOSED SOLUTIONS

Sylvain Fauveaux, Amaury Lefort

The direct lightning protection industry is highly dependent on the use of copper. Indeed, direct lightning protection installations use a lot of copper. Gradually over the past few years, the copper market has been under tension for several reasons: reduced production during the Covid19 crisis, declining mining yields, prices increasing following the economic recovery, more expensive production due to the increase in energy prices and its supply following the Russia-Ukraine war, the strong growth in demand for copper required by new technological uses. In the medium/long term, the main threat lies in the fact that the shortage is in focus. In addition, global warming, which imposes restrictions on CO2 emissions

and tensions on the electricity market (limited supply and high price per MWh) forces us to think about alternatives. The direct lightning protection industry is therefore also concerned. Alternatives are possible to delay the shortage of copper by using alternative materials, or by using less demanding installation techniques. However, the carbon and energy footprints must be considered depending on the solutions chosen, in particular with a view to social responsibility. In this paper, we will look at the reduction of materials in the design of the ELPS, and in the use of alternative materials. Substantial gains are possible. The most efficient way to reduce the quantity of metal involved in an ELPS is to use Early Streamer Emission Air Terminals (ESEAT) that provide larger and safe protection zones with much fewer capture devices and downconductors compared to the conventional systems.

02:40 – 03:00 PM

Room 3

REVIEW OF AN AIRBORNE LIGHTNING DETECTION SYSTEM AND ATMOSPHERIC CONDITIONS DURING FLIGHTS IN COASTAL THUNDERSTORM CONDITIONS

Zachary Milani, Leonid Nichman, Edgar Matida, Mathieu Lachapelle, Cuong Nguyen, Eric Bruning, Mengistu Wolde, Greg M. McFarquhar, Pavlos Kollias, R. Timothy Patterson

Lightning poses a significant risk to aircraft safety, especially as the aviation industry transitions from conventional to hybrid and electric aircraft. It is becoming more common to rely on remotely piloted aircraft systems (RPAS), unmanned aerial vehicles (UAVs), and vertical take-off and landing aircraft (VTOLs) for all-weather aerial activities like transportation and the delivery of goods. Important flight operations decisions of postponing or diverting flights due to severe weather are reliant on accurate information about the presence of lightning and its type, location, flash rate, and information about the ambient conditions inducive of lightning. At present, numerous well-established ground and satellite-based methods exist for monitoring lightning activity. At best, aircraft can receive weather updates from ground sources every 2.5 to 5 minutes, but it is not uncommon for updates to be intermittent due to connection and service stability issues.

Therefore, an aircraft-mounted lightning locator may be the most practical source of real-time lightning information for pilots. Detailed performance metrics with uncertainties for commercial airborne lightning locating systems are typically not published and the literature investigating such systems is limited. Here, we present airborne lightning measurements obtained using the commercially available Stormscope Weather Mapping System (WX-500 Series 2; ~1 to 100 kHz). This single-station directionfinding sensor was installed on the Convair-580 research aircraft owned and operated by the National Research Council of Canada (NRC) during the 2022 Experiment of Sea Breeze Convection, Aerosols, Precipitation, and Environment (ESCAPE)

campaign in Houston, Texas, which targeted convective updrafts (up to 30 m/s). Stormscope performance is assessed through comparisons to highquality datasets of total lightning activity provided by the Houston Lightning Mapping Array (HLMA; 60 to 66 MHz) and the GOES - Geostationary Lightning Mapper (GLM; 777 nm). Preliminary results show the Stormscope registered lightning activity in less than 60% of detection windows containing at least one HLMA flash. When considering only single and clustered flashes, Stormscope bearing accuracy was ±12° while the range was often overpredicted and with a large spread. Also presented are in-flight microphysics data including high-resolution images of single particles within in a lightning producing cell.

03:00 – 03:20 PM

Room 1

IMPACT OF GROUNDING SYSTEM MODELING ON OVERVOLTAGE WAVEFORMS FOR DIRECT LIGHTNING STRIKES AT WIND TURBINES

Wagner Costa da Silva, Walter Luiz Manzi de Azevedo, Anderson Ricardo Justo de Araujo, Jose Pissolato Filho

Wind farms represent a fundamental component of the worldwide transition to renewable energy. However, wind turbines are exposed to lightning strikes due to their tall structures. In this context, adequate modeling of wind turbines is essential to determine the generated overvoltages during a lightning strike. One of the key parts of the wind turbine is the grounding system, where lightning current must be dissipated into the soil, ensuring that a safe earth potential is maintained. This paper investigates distinct grounding system models and their impact on the generated overvoltages in the nacelle and tower base when a wind turbine is struck by lightning. The analysis is performed considering a realistic wind turbine grounding system (WTGS) using the full-wave electromagnetic FEKO/Altair Engineering. to calculate its harmonic impedance for the frequency range 100 Hz to 10 MHz. Based on this impedance, the low-frequency resistance RLF and the impulse impedance Zp are computed. Soils represented by four distinct values of low-frequency resistivity ρ0 are assumed: 500, 1,000, 2,500 and 5,000 Ωm. The software ATP-EMTP. is used for the circuit model of the wind turbine and numerical simulations. Results demonstrated that significant differences can be obtained for the on the GPR and overvoltage waveforms at the nacelle and tower base, where the use of RLF tends to underestimate the transient responses whilst Zp is a more adequate and concise representation of the grounding system.

10 Sept

03:00 – 03:20 PM

Room 3

URBAN AIR MOBILITY OPERATIONS: EVALUATING EXPOSURE TO LIGHTNING STRIKES

Evandro F. Ledema, Kleber P. Naccarato, Marina G. Sousa

The escalating demand for innovative modes of commuting within sprawling urban conglomerations has spurred the necessity for new transportation services. Predominantly utilizing electric vertical takeoff and landing (eVTOL) technology, Urban Air Mobility (UAM) envisages operations at lower altitudes and speeds, facilitating connectivity between vertiports across cities or acting as shuttles linking various points within airports. UAM is subjected to rigorous regulatory scrutiny, reflecting the innovative characteristics inherent in its design. An important concern in regulatory considerations is the effect of the electric environment on UAM operations. Notably, the eVTOL requires a lightweight design to meet operational viability, constrained by the weight limitations imposed by its electric motors. Using primarily composite materials for its construction results in a lighter structure, albeit offering a distinct level of lightning protection compared to metallic structures. Given the multiple challenges and complexities inherent in its operation, understanding the electrical environment where the eVTOL will operate in cities is of great value. In urban areas, aerosols and heat islands enhance lightning activity by intensifying the severity of thunderstorms. Therefore, the trajectory of UAM flights will require navigating around cumulonimbus clouds and associated convective structures, which pose a significant risk of lightning incidence and strong wind gusts. Based on these considerations, this work investigates how urban atmospheric environments affect the operation of eVTOLs by analyzing lightning strike probabilities in dense cityscapes. Through a literature review and theoretical frameworks, the study examines the regulatory landscape, technological constraints, and environmental characteristics to assess this critical aspect of UAM safety and contribute to the ongoing discussion on UAM, specifically concerning lightning exposure and possible strategies to mitigate incidents and/or accidents.

04:00 – 04:20 PM

Room 1

RESEARCH ON LIGHTNING ELECTRIC AND MAGNETIC FIELD EFFECT TEST

Xiu Xiong, Xiaoyu Fan, Shaohua Li, Kai Liu

Lightning indirect effects cannot be fully simulated by conducting lightning transient sensitivity tests according to DO160G. To simulate the electromagnetic field effects caused by nearby lightning strikes, it is necessary to conduct lightning pulse electric and magnetic field effects tests. The test methods are introduced in MIL-STD-464C “Electromagnetic Environmental Effects Requirements for Systems.” In this paper, the pulse electric field and pulse magnetic field test systems

are built based on MIL-STD-464C. The uniformity of the electric field and magnetic field distribution and the deviation from the theoretical calculation value are studied, and the calculation method of the rate of change is discussed. The test and analysis results show that the maximum change rate of magnetic field strength and electric field strength can meet the requirements of MIL-STD-464C and can be applied to evaluate the lightning electromagnetic field effects.

04:00 – 04:20 PM

Room 3

ANALYSIS OF THE EBRO LIGHTNING MAPPING ARRAY DETECTIONS OF AIRCRAFT IN FLIGHT PRODUCING ELECTRICAL DISCHARGES

Eduard Martin, Joan Montanyà, Jesús A. López, Oscar van der Velde, Nicolau Pineda, D. Romero, Carlos A. Morales

In this work we summarize the detections of electrical discharges produced from flying aircraft identified by the Ebro Lightning Mapping Array network (eLMA). From the period from June 2023 to February 2024 a total of 79 aircraft were detected. We found that the duration of the periods during which aircraft produce electrical discharges ranges from few seconds up to ten minutes. During these periods aircraft flies several tens of kilometers. The typical altitudes where aircraft were detected are 11.4 km, 8.8 km, and 7 km. Detected aircraft were mostly cruising or ascending. Using Flightradar24 we identified that the most frequent aircraft appearing in our data was the B787 followed by the B737, A320 and A321.

04:20 – 04:40 PM

Room 1

MATERIAL CHARACTERIZATION FOR PROPAGATING BRUSH DISCHARGE THREAT ANALYSIS

Crislane Silva, Eduardo Ferreira, Julio Santos and Janaina Nicolo

This paper discusses the threat of electrostatic discharge in flammable gas/vapor areas, particularly in aircraft fuel tanks. When an object in the fuel tank comes into contact with charged fuel, it can become charged itself. This charge accumulation on dielectric surfaces can lead to various types of electrostatic discharges, ranging from harmless corona glow discharges to potentially dangerous propagating brush discharges (PBD) that can ignite flammable gas/vapor. Several physical parameters determine the conditions necessary for a PBD, including material dielectric strength and thickness, surface charge density, humidity, material properties, altitude, and conductor substrate type/properties. To comply with regulations for preventing electrostatic threats, it is necessary to evaluate the electrostatic performance characteristics of all materials used in aircraft fuel tanks. This paper also proposes and describes several test approaches for evaluating and qualifying materials used inside fuel tanks, including surface and bulk resistance tests, charge relaxation tests, dielectric withstand voltage tests, and propagating brush discharge tests.

10 Sept

04:20 – 04:40 PM

Room 3

UPDATED VERSION OF A LOW-COST REMOTE DEVICE FOR MEASURING LIGHTNING CURRENTS

Gilberto Teodósio, Lucas Guimarães, Gustavo Alves, Lucas Silva, Matheus Martins, Deilton Gonçalves, Tulio Carvalho, Miguel Guimarães e Listz Simões

This paper highlights the recent advances in the design of a low-cost device that has been developed for measuring lightning return currents. Updates have been implemented in both hardware and software to improve data recording, communication, and data reliability. These improvements enable measurements at a sampling rate of 10 MS/s over a 4-ms period, allowing accurate recording of first return current events. Results obtained from tests in a high-current impulse generator are presented and discussed.

04:40 – 05:00 PM

Room 1

MULTI-CHAMBER ARRESTER WITH IMPULSE ARC QUENCHING FOR PROTECTION 13.8 KV OVERHEAD LINES

Georgy Podporkin, Urij Kretov, Alexander Sotnikov, Sergey Rumyantsev

Development results of arrester for 13.8 kV overhead power lines against induced overvoltages are presented. The arrester quench impulse current arc without power follow current and have many advantages at conventional arresters.

04:40 – 05:00 PM

Room 3

EVALUATING STRATEGIES FOR AUTOMATICALLY DETECTING THE LONG CONTINUING CURRENT SIGNATURES ON ELECTRIC FIELD WAVEFORMS OF LIGHTNING EVENTS OCCURRING IN THE METROPOLITAN AREA OF BELO HORIZONTE

Lucas Viegas, Gustavo Barbosa, Karine Teixeira, Matheus Vianna, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Listz Simões, Miguel Guimarães, Marcelo Arcanjo, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi

This paper discusses the results of a computational approach in Python for automatically detecting Long Continuing Currents (LCCs) in lightning data measured in the metropolitan region of Belo Horizonte, Minas Gerais. The authors developed a computational routine to reliably output LCC characteristics, such as initial and final time, duration and amplitude variation per time. This method enables fast, accurate identification of severe LCCs in large datasets to support statistical analysis. The results show positive responses from the code for the cases of negative and positive LCC analyzed.

September 11

10:40 – 11:00

Room 1

STUDY ON ELECTROSTATIC CHARACTERISTICS OF VALVE HEAD MATERIALS IN AIRCRAFT OXYGEN SYSTEM

Zemin Duna, Wei Yan, Xiaoliang Si, Zhibao Li

In the process of aerating the aircraft oxygen system on the ground, the insulation material of the check valve head and the valve body spring frequently contact and separate to produce static electricity. In order to avoid the explosion accident caused by electrostatic discharge, the separation electrostatic potential of two materials commonly used in aerating valve head was studied: The effects of contact pressure, environmental relative humidity, separation speed and other factors on the separation electrostatic potential of different materials were investigated. It was proved that the separation electrostatic potential of nylon material can reach up to 1000 volts, and it has the possibility of electrostatic discharge, and the antistatic property of nylon 1010 material is weaker than that of polytrifluorochloroethylene. This will provide experimental basis and research direction for further exploration of insulating materials used in aircraft oxygen system.

10:40 – 11:00

Room 3

FLAMMABLE GAS MIXTURE TEST FIXTURE STANDARDIZATIONS

Sofia Graham, Derek Tuck, Brian Egenriether, Philipp Boettcher

Lightning strike and static electricity ignition hazard testing for aircraft typically follow one of two test methods per SAE ARP5416A. These two methods detect the presence of an ignition hazard through either (1) the combustion of a flammable gas mixture ignitable by a 200 microJoule (μJ) voltage arc or (2) light emission greater than that of a 200 μJ voltage arc. The instrumentation and test conditions of the voltage arc source is not fully constrained by industry standards which could lead to overly conservative or erroneous results when performing ignition hazard testing and thus cause costlier or ineffective remediations and designs for EME protection. Understanding the sensitivities of the two test methods to different parameters that affect the optical and incendive properties of the arc is the main goal of this paper. Such parameters include the spacing of the electrode, varying the temporal waveform, and identifying the effects of the ambient humidity. Additionally, we provide recommendations on characterizing the voltage arc energy with temporal current and voltage measurement combined with numerical simulations and analysis of parasitic impedances. We also give potential alternative methods for verifying the ignitability of the flammable gas

mixture and provide an equipment design for the flammable gas mixture test method. In order to deliver these results, two phases of testing are conducted with the aforementioned variables using the Boeing Company patented fixture, Patent Number 10,620,179 (Systems and Methods for Non-Flammable Indication of Incendivity) and Number 10,738,754 (Rapid Sample Ignition Test System). We then explore the use of the partial pressures alternative by exploring the sensitivity of the flammable gas to partial pressures. This method is discussed in greater detail in the draft of the upcoming Revision B of SAE ARP5416.

11:00 – 11:20

Room 1

RADIATION HAZARD OF BALL LIGHTNING

Mikhail L. Shmatov

The observational data corresponding to the assumption about emission of high-energy photons by ball lightning and, in particular, to the assumption about the high radiation hazard of some ball lightning are presented. The main points of the ball lightning model explaining these data are also presented. According to the model, ball lightning has a core consisting of clouds of electrons and almost totally ionized ions which oscillate with respect to each other. The possibility and expedience to check these assumptions and the model, in particular, to create ball lightning in the experiments with ordinary or rocket-triggered lightning, are considered.

11:00 – 11:20

Room 3

BENEFITS OF COMPUTATIONAL ELECTROMAGNETIC ANALYSIS IN AIRCRAFT FUEL SYSTEM LIGHTNING CERTIFICATION

Massoud Sadeghi, William Coleman

This paper discusses some important benefits of using simulation in the compliance process for 25.981 Fuel Tank Ignition Prevention regulation. It provides this in the context of a real-world application where simulation was used in conjunction with test data to determine certification levels for an aircraft fuel system.

11:20 – 11:40

Room 1

AN END-TO-END PHYSICS-BASED MODELING APPROACH TO PRECIPITATION STATIC

Derek Tuck, Brian Egenriether, Nitish Chandra, Kyu-Pyung Hwang

Precipitation static (P-static) interference is a complex phenomenon that occurs when an aircraft or its components become electrically charged and discharge rapidly, potentially causing radio interference. This interference can disrupt communication through High Frequency (HF) and Very High Frequency (VHF) antennas, as well as pose risks to navigation systems such as the Automatic Direction Finder (ADF) and Very High Frequency Omnidirectional Range

station (VOR). Traditionally, certifying P-static performance requires expensive and time-consuming flight tests, involving extensive planning and the involvement of multiple engineers and technicians. Moreover, relying solely on flight testing limits the design solutions that can be implemented, particularly those affecting the aircraft's surface. To address these challenges, the Boeing Research and Technology Electromagnetic Effects team is pioneering an effort to predict P-static phenomena through a physics-based modeling workflow. The primary objective of this work is to develop models that can inform design solutions and requirements, enabling efficient and confident resolution of P-static issues. This research involves the creation of detailed electromagnetic models that encompass every aspect of the modeling workflow. It begins with understanding the charging mechanisms responsible for P-static and progresses to the coupling of radiated fields with the relevant antennas that result from dielectric breakdown. By following this comprehensive approach, the team aims to demonstrate the feasibility of an end-to-end model-based engineering workflow for physics-based modeling of P-static hazards. The outcome of this research is a set of models that have the potential to alleviate the cost and time burden associated with demonstrating compliance to Federal Aviation Administration (FAA) P-static requirements. Relying on these models can expedite the design process, confidently implement P-static solutions, and ensure compliance with regulatory standards. The ongoing research by the Boeing Research and Technology Electromagnetic Effects team represents a significant step towards mitigating the challenges posed by P-static interference. Through the development of physics-based models, this work aims to provide a more efficient and reliable approach to addressing P-static issues, ultimately enhancing the safety and performance of aircraft systems.

11:20 – 11:40

Room 3

SIMULATION OF CONTINUOUS ARC WITH SEMI-IMPLICIT SCHEME AND MESH ADAPTATION

Gabriel Barreau, François Pechereau, Benjamin Khiar, Julien Vanharen, Philippe Lalande, Fabien Tholin, Guillaume Puigt, Frédéric Alauzet

In this work, modeling a continuous arc powered by a pointed cathode and a flat anode was carried out. For this simulation, a new semi-implicit scheme was implemented in the MHD code Taranis developed at ONERA. This semi-implicit method is derived from an existing method dedicated to perfect gases. In this work, it was extended to real gases. To significantly reduce the computational costs represented by 3D meshes, the Taranis code is coupled with feflo.a, an anisotropic mesh adaptation framework developed at INRIA. After the presentation of this new workflow, it is validated with the 3D simulation of a free-burning arc in argon.

11 Sept

11:40 – 12:00

Room 1

THE NUMERICAL SIMULATION METHOD OF CHARGING CURRENT IN ELECTROSTATIC DEPOSITION ENVIRONMENT OF AIRCRAFT

First Duan Zemin, Xiaoliang Si,Tong Chen4, Shanliang Qiu, Zhang Song, Zhibao Li, Gong Hanlin, Huang Yeyuan

The charging current density is an important indicator to guide the design of aircraft deposition electrostatic protection. The effective area coefficient K is calculated novelly using the concept of effective projected area. The S-A turbulence model and particle drag model are used to improve the calculation formula in the standard, and a certain type of aircraft is used as an example to simulate the flow field and particle tracking. It is found that the larger the particle diameter, the larger the effective projected area; the higher the flight speed, the more the number of particle collisions; the charging current density increases with the increase of the cruising altitude. Finally, it is concluded that the maximum charging current density of the aircraft is 395μA/m2, which is very close to the actual observation value and the error is within 1.25%. The research in this paper has certain guiding significance for the design of aircraft deposition electrostatic protection.

11:40 – 12:00

Room 3

FROM KEROSENE TO HYDROGEN AIRCRAFT: THE NEW LIGHTNING PROTECTION CHALLENGES

Bigand Audrey, Revel Ivan, Emma Roubaud, Flourens Franck

Hydrogen propulsion is one step towards aviation industry decarbonisation. Dihydrogen element used as a fuel for aviation is an opportunity but presents also many challenges. There are significant differences between hydrogen and kerosene in operation and for safety management. This paper presents a state of the art on hydrogen flammability demonstrating that hydrogen systems cannot be managed in the same way as kerosene systems and the lightning protection strategy must necessarily be reviewed in depth. Moreover, the fuel characteristics (temperature and propensity to leak) strongly impact the system robustness and behaviour and bring specific inherent risks. As a consequence, the lightning compliance demonstration methodology developed for kerosene systems has to be reconsidered. To start on this new subject, an investigation has been achieved on a critical liquid hydrogen distribution component, a double wall pipework coupling, coming from on-ground industries. The analysis of the intrinsic robustness to lightning direct effects with the testing methodology developed considering the cryogenic environment is detailed. This enables a simplified lightning compliance demonstration for metallic coupling technologies that could be extrapolated to the complete hydrogen system.

11 Sept

01:40 – 02:00 PM

Room 1

ANALYSIS OF ELECTRICAL BONDING ARRAY EFFECTS ON THE PROTECTION OF ELECTRO-ELECTRONIC SYSTEM EXTERNALLY INSTALLED ON SMALL COMPOSITE AIRFRAME

Diego Faria Amaral, José Antônio de Souza Mariano, Lollan Naru Nonaka Rodrigo Cabaleiro Cortizo Freire, Sidney Osses Nunes

Protection of electro-electronic systems installed on composite aircraft requires attention to the protection against induced effects due to lightning strikes, especially for small size vehicles. This paper intends to provide an analysis of the Electrical Bonding Network (Array) (EBN) configuration for small composite airframes. The main objective of this study is to verify the efficiency of the Electrical Bonding Network (EBN) in the protection of an electro-electronic sensor system exposed to direct lightning strike. The system will be composed of sensor and the respective wiring routed near to the internal composite skin of the small aircraft. The results found for the proposed configurations of protection are presented and discussed, providing also a comparative analysis among them and the respective conclusions.

01:40 – 02:00 PM

Room 3

NUMERICAL MODELING OF INDUCED TRANSIENTS ON A/C WIRING: USE OF FDTD SIMULATIONS FOR FALCON 6X CERTIFICATION

F. Terrade, F. Tristant

For many years, Dassault Aviation has been using 3D simulation, with an FDTD solver (Finite Difference – Time Domain), in its general process for HIRF and Lightning design and certification for systems (especially wiring) and fuel-tank-safety. For the computation of Lightning induced currents on A/C wiring, Dassault Aviation has proven its capability to properly reproduce transients on cable bundles with TEMSI-FD FDTD solver developed by XLIM Institute. For the first time, Dassault Aviation has included FDTD simulations of lightning indirect effects (LIE) in the Falcon 6X certification process, to justify and complement ground test measurements of Actual Transient Levels (ATL).

02:00 – 02:20 PM

Room 1

LIGHTNING CURRENT TESTS OF SEGMENTED DIVERTER STRIPS WITH COMPONENT A AND D

Felicitas Modlinger, Christian Karch, Fridolin Heidler

Segmented diverter strips are used for aircrafts in order to prevent lightning flashes from puncturing the radome wall and from

damaging the antennstems inside. The diverter strips have to withstand the high-current loads of the first or subsequent return stroke, which includes the protection against the long-duration currents of the initial continuous current and the continuing current. In zones where a first return stroke is likely, the so-called current component A applies with the current maximum of 200 kA and the action integral of 2.0 x 106 A2s. In zones which are only exposed to the subsequent return stroke, the weaker component D is appropriate, with the current maximum of 100 kA and the action integral of 0.25 x 106 A2s.

Objective of this paper is the analysis of the current carrying capacity of segmented diverter strips. For this purpose, three types of segmented diverter strips were tested with the current components A and D. The diverter strips were equipped with round buttons of 1 mm, 2 mm and 3 mm of diameter. The tests revealed that diverter strips with the smaller buttons of 1 mm and 2 mm can withstand a higher current load compared to diverter strips with the larger buttons of 3 mm.

02:00 – 02:20 PM

Room 3

NUMERICAL MODELING OF INDUCED TRANSIENTS ON AIRCRAFT WIRING WITH A HYBRID FDTD/MTLN APPROACH

T. Strub, N. Muot, C. Girard, F. Terrade, F. Tristant, N. Bui, C. Guiffaut, A. Reineix

For many years, Dassault Aviation has been using 3D simulation, with an FDTD solver (Finite Difference – Time Domain), in its general process for HIRF and Lightning design and certification for systems (especially wiring) and fuel-tank-safety. For the computation of Lightning induced currents on A/C wiring, Dassault Aviation has proven its capability to properly reproduce transients on cable bundles with TEMSI-FD FDTD solver developed by XLIM Institute. Recently, a novel hybrid FDTD+MTLN approach, with a common mode reciprocal coupling between the methods, has been studied and developed, with the aim to be applicable at full A/C level for future certification purposes.

02:20 – 02:40 PM

Room 1

DESIGN OF A SMALL FIELD MILL NETWORK FOR CLOUD MODELLING

Valter Garcia, Miguel Guimarães, Listz Araújo, Tulio Carvalho Lucas Viegas, Deilton Gomes, Marcelo Saba, Moacir Lacerda

This study focuses on monitoring atmospheric discharge events using a network of electric field mills (EFMs). The EFMs, specifically Campbell Scientific CS110 models, were deployed in the Utah desert, USA, to measure static electric fields. Data collection utilized an Internet of Things (IoT) architecture with MQTT protocol for remote data transmission, enhancing efficiency the evaluation of 300 IC pulses and 300 PB pulses, it was possible to determine that the average

total duration of these events is basically the same, being 14.07 and 13.02 µs, respectively, with the main difference and reliability in harsh environments. The study demonstrated the effectiveness of this approach in capturing real-time electric field data during thunderstorms, correlating these measurements with lightning location system (LLS) data. Key findings include temporal patterns of electric field variations corresponding to lightning activity, highlighting significant peaks during storm events. Future research aims to develop a storm.

02:20 – 02:40 PM

Room 3

MODELLING LIGHTNING INDIRECT EFFECT ON AERONAUTIC SYSTEMS: VALIDATION FROM IMPROVED ANALYTICAL FORMALISM AND NUMERICAL SIMULATIONS

S. Lalléchère, D. Cvetkovic, L. Pniak, Y. Corredores, V. Melchor, A. Piat, F. De Daran, P-E. Lévy, L. Pichon

This paper focuses on an innovative approach based on the PEEC (Partial Element Equivalent Circuit) method and the analytical integration of its coupling equations. This work is devoted to the recent implementation of a surface-based formalism, referred to here as S-PEEC. The theoretical principles and assumptions are reminded, and the methodology is described through a generic test case considering lightning current distribution simulations. The comparison of S-PEEC results with commercial tools simulations validates S-PEEC efficiency and precision. Finally, the S-PEEC advantages for pre-compliance simulations are exploited through realistic aeronautic test case scenarios.

02:40 – 03:00 PM

Room 1

ANALYSIS OF LIGHTNING-INDUCED EFFECTS ON SMALL ELECTRIC AIRCRAFT

Renan H. M. Callegari, José Antônio S. Mariano, Rodrigo Cabaleiro C. Freire, Ricardo A. de Araujo, José Pissolato Filho, Gabriel T. C. Francisco

The evolution of electric propulsion is transforming aviation, making small electric aircraft more viable and sustainable but presenting safety challenges, particularly from lightning strikes. This article presents simulations and analyses of lightning-induced electromagnetic effects on different aircraft structures, focusing on structural vulnerability and protection measures. Using Dassault CST Studio Suite 2023, the study compares aluminum alloy and carbon fiber composites with metallic mesh. The results indicate that lightweight composite structures need extra protection to meet safety standards, providing insights for enhancing electric aircraft robustness against electromagnetic events.

11 Sept

02:40 – 03:00 PM

Room 3

THE EVOLUTION OF INDIRECT EFFECTS LIGHTNING QUALIFICATION TEST STANDARDS FOR AIRBORNE PRODUCTS: AN OVERVIEW OF EUROCAE ED 14 / RTCA DO-160 SECTION 22, REVISION G TO H

Vincent MELCHOR , Bertrand CHATAIN

In 2007, Andy Plumer published a White Paper, so called «A Significant Error in Sensing of Limit Voltages in Cable Bundle Tests with the Cable Induction Method of RTCA D0160/EUROCAE ED 14 Section 22 and a Proposal to Correct this Error." Following the release of EUROCAE ED-14G / RTCA DO-160G in 2010, the SAE AE-2 committee launched some "Round Robin" testing in 8 North American test laboratories to better characterize the findings outlined in that paper. The EUROCAE WG-31 committee also coordinated these tests utilizing the same test setup in Europe, involving 9 European test laboratories. The test data provided by the participating test laboratories highlighted some discrepancies between test results, especially when dealing with mixed impedance bundles and different types of lightning generators. This paper presents an overview of the activities conducted over the 7+ year investigation and outlines a number of key reasons for changes that resulted in the revision of Section 22 for EUROCAE ED-14H / RTCA DO-160H. Two major changes made to the revision of Section 22 are detailed in this article. Many considerations related to best practices and cautions will also be more deeply developed in the updated User Guide, EUROCAE ED-234 / RTCA DO-357. The use of this User Guide is strongly recommended during requirements capture, test preparation and test execution. Before the final publication of ED-14H/DO-160H and the revised User Guide, an interim EUROCAE Report (ER) will be published to provide advanced guidance to help cover this time lapse and to address the most significant aspects and genesis of Section 22's evolution.

04:00 – 04:20 PM

Room 3

WIND TURBINE BLADES AND REDUCING LIGHTNING DAMAGE THROUGH RETROFITS

Billy Martin, Aaron Jones, Harian Sharpe

The development of ShockTapeTM is ongoing, from both a retrofit and clean sheet design aspect. The most recent results of the engineering, laboratory testing, and in-field installations will be examined in this paper. These types of tests include robust environmental testing, electrical testing (both high voltage and high current), adhesive strength testing, in-field examination of weather tolerance, the ability of ShockTape to transfer lightning to the existing lightning protection system, and comparison to alternative retrofit lightning protection devices.

Lightning strikes continue to be an extremely perplexing problem for the wind turbine industry to solve as the industry expands into more areas of the world

where environmental conditions can be extremely destructive, and repairs are therefore expensive. Compounding the issue is the fact that the turbine blades continue to increase in size and complexity, both in aerodynamic shape and advanced material composition.

04:20 – 04:40 PM

Room 3

ASSESSING THE TIME DIFFERENCE OF ARRIVAL AND OPTIMIZATION TECHNIQUES TO DETERMINE STRIKE LOCATION OF LIGHTNING EVENTS OCCURRING IN THE METROPOLITAN AREA OF BELO HORIZONTE

Karine Teixeira, Lucas Viegas, Gustavo Barbosa, Matheus Vianna, Matheus Martins, Listz Simões, Miguel Guimarães, Marcelo Arcanjo, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi

This work aims to define the optimal placement of a finite number of sensors to maximize the coverage area and lightning location performance in the Belo Horizonte region. The analysis evaluates the Least Squares (LS) approach to solve the non-linear Time Difference of Arrival (TDoA) equations, using different sensor configurations and the Monte Carlo method. The impact of removing individual stations from the base case was evaluated, as well as the performance of network expansion. The results show that expanding from 5 to 7 sensors provides similar performance to expanding to 8 sensors, considering the available site options. Overall, the document presents a robust approach to determine the optimal sensor network configuration to improve the accuracy of lightning location in the Belo Horizonte area.

04:40 – 05:00 PM

Room 3

A NOVEL NETWORK FOR DETECTING LONG CONTINUING CURRENTS IN THE METROPOLITAN AREA OF BELO HORIZONTE

Miguel Guimarães, Listz Simões, Karine Teixeira, Lucas Viegas, Gustavo Barbosa, Matheus Drumond, Matheus Martins, Alberto Torres, Maria Luiza Pereira, Manoel Gonçalves, Valter Garcia, Tiago Pinto, Deilton Gomes, Túlio Carvalho, Guilherme Silva, Elias Freitas, Marcelo Arcanjo, Marcelo M. F. Saba, Paola Lauria, Istvan Kereszy, Tamas Kereszy, John Kern, Giovanna Pedro, Caroline Comeau, Paulo Victorino, Dorottya Fuzy, Krisztian Pomazi

This paper describes the first experimental results of a new lightning detection network installed in the metropolitan area of Belo Horizonte, Brazil, with the specific purpose of evaluating the occurrence of lightning continuing currents, which are currently not detected by conventional Lightning Location Systems. It is known that these current components are responsible for causing severe thermal damage in power systems, as well as the ignition of large-scale wildfires. The distinctive aspect of this network is the type of sensor deployed - it features two channels whose technical specifications allow the recording of physical processes within a wide frequency range. Throughout the text, typical waveform examples of lightning electric fields are presented. Additionally, a preliminary statistical study regarding the average duration of these continuing currents is reported, and a brief discussion is provided.

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